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On the Variation of T Centauri. By Alex. W. Roberts, D.Sc.

The variation of the star *T Centauri* (Chandler, 4896), R.A. 13^h 36^m 2^s (1900), Dec.—33° 5′·5, was discovered in 1894 by Colonel Markwick, and independently the same year by Professor Pickering.

The Harvard notification of its discovery is given in the *Astronomische Nachrichten*, No. 3269, p. 72, and that of Colonel Markwick in the *Journal of the British Astronomical Association*, vol. v., p. 247. As far back as 1890, however, its variation was suspected by Kapteyn from an examination of the Cape Photographic Durchmusterung plates. His note on the variable magnitude indicated by the Cape Photographs is contained in *Astronomische Nachrichten*, No. 2987.

The following papers on the variation of *T Centauri* have already appeared in the *Monthly Notices*—

Vol. lvi., p. 35 (Markwick)
„ lvi., p. 347 (Roberts)
„ lvi., p. 500 (Roberts)
„ lviii., p. 513 (Markwick)

in which the nature and period of the star's variation are set forth.

Three years have now elapsed since the last of the four foregoing papers was published, and although observations made during these years have not in any way altered the general conclusions come to then, I think sufficient data have accumulated to enable a very accurate determination of the chief elements of the star's variation to be made.

In arriving at a determination of the period of *T Centauri*, or of any other long-period variable, it should be remembered that the possibility of the period being subject to a secular inequality is not unlikely. Because of this it is as well to include in the investigation only such maxima and minima as have been determined from a full-light curve, or at least from observations so situated on the light curve that they indicate, within a certain margin of error, the date of maximum or minimum brightness.

I have in other papers called attention to the uncertainty which always attaches to isolated meridian observations of magnitude; they are indeed of very little value as an aid to a definitive determination of light period unless the interval which separates the several dates is sufficiently great to compensate for the uncertainty in brightness.

If, of course, a meridian observation is manifestly taken near a maximum or minimum phase, then its value, as an aid to a

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determination of the period of the star, is considerably enhanced; but even in this case, the range in brightness is usually so irregular, amounting in the case of *T Centauri* to two magnitudes, that there is always some slight uncertainty with regard to a maximum or minimum date estimated from meridian observations alone.

I propose therefore in the present investigation to base a determination of the period of *T Centauri* upon: (1) Recent systematic observations of magnitude; (2) All available data.

The first portion of the investigation will yield elements which satisfy present observations. If the period of the star is subject to secular inequality, these elements may not satisfy more remote observations.

In the following two series, Tables I. and II., are given the various maxima and minima determined rigorously during the past six years.

All the Lovedale observations were made with a 1-inch telescope, except where the star was passing through its maximum phase. Its brightness then allowed naked-eye estimates to be made.

Table I.

Determinations of Maxima.

Rotation No.	Date.	Julian Day.	Mag.	Observer.
		J	m	
1	1895 June 8	2413353	5·3	Markwick
2	June 10	2413355	5·8	Roberts
3	Sept. 10	2413447	6·0	,,
4	1896 March 8	2413627		Tebbutt
5	March 10	2413629	5·4	Roberts
6	June 16	2413727	6·0	,,
7	June 18	2413729	6·4	Markwick
8	Sept. 3	2413806	5·7	Roberts
9	1897 June 1	2414077	6·2	Markwick
10	1898 June 3	2414444	6·6	,,
11	Sept. 1	2414534	5·9	Roberts
12	1899 Feb. 25	2414711	5·2	,,
13	June 3	2414809	6·2	,,
14	Aug. 28	2414895	5·5	,,
15	1900 Feb. 25	2415076	6·0	,,
16	May 24	2415164	5·6	,,
17	Aug. 25	2415257	6·1	,,
18	1901 May 23	2415528	5·9	,,
19	Aug. 22	2415619	5·8	,,

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TABLE II.

Determinations of Minima.

Rotation No.	Date.	Julian Day.	Mag.	Observer.
		J	m	
1	1895 April 26	2413310	9·0	Roberts
2	April 27	2413311	10·0	Markwick
3	July 30	2413405	8·0	Roberts
4	1896 April 26	2413676	8·9	,,
5	April 30	2413680	9·9	Markwick
6	July 24	2413765	8·7	Roberts
7	1898 April 18	2414398	9·2	Markwick
8	1899 April 10	2414755	8·9	Roberts
9	July 13	2414849	8·6	,,
10	1900 April 12	2415122	7·4	,,
11	July 13	2415214	8·3	,,
12	1901 April 10	2415485	7·4	,,
13	July 12	2415578	8·4	,,

Let now the following values be considered :

$P + \Delta p$ = period of variation ;
$T_M + \Delta t_M$ = epoch of maximum ;
$T_m + \Delta t_m$ = epoch of minimum ;
m = annual amount of secular variation of period ;
E = number of periods, reckoning from the epoch ;
J = Julian day of observation as given in column 3 of Tables I. and II.

Then it is evident that the following equations represent the relation of the various quantities to one another :

With regard to Table I. :

$$(T_M + \Delta t_M) + E\{(P + \Delta p) + \frac{E}{2}m\} = J$$

that is,

$$\Delta t_M + E\Delta p + \frac{E^2}{2}m = \{J - (T_M + EP)\} \ldots \qquad \ldots (1)$$

and with regard to Table II.,

$$\Delta t_m + E\Delta p + \frac{E^2}{2}m = \{J - (T_m + Ep)\} \ldots \qquad \ldots (2)$$

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We readily obtain from Tables I. and II. the following approximate values of T_M, T_m and P,

$$T_M = 2415075^{J},$$
$$T_m = 2415033^{J},$$
$$P = 90^{d}{\cdot}4.$$

With these assumed values and the values of J contained in column 3, we form equations of condition of the type indicated in (1) and (2).

It is not necessary to burden the paper with the statement of these thirty-two equations, or with the several steps in their solution.

The final result is as follows :

$$\begin{aligned} & \quad\ \ \text{d.} \\ \Delta t_M &= +1{\cdot}1 \\ \Delta t_m &= -1{\cdot}0 \\ \Delta p &= +0{\cdot}07 \\ \Delta m &= \ \ 0{\cdot}000 \end{aligned}$$

This gives as the final elements of *T Centauri* for the year 1901 :

Epoch of maximum $= 2415076{\cdot}1$
Epoch of minimum $= 2415032{\cdot}0$
$M - m = 44^{d}{\cdot}1$
Period $= 90^{d}{\cdot}47$

The value of *m* obtained from the equations indicates that for the six years 1895–1901 the period of *T Centauri* was constant. We must not however infer from this that the period is always constant. This does not follow.

With the above corrected elements we now compute theoretical dates for comparison with the observed dates. This comparison is given in the following tables. Column 2 gives the values of E at the date of observation, column 3 the observed date ; column 4 the computed date, and column 5 the residual (O – C).

Table III.

Maxima Dates.

Rotation No.	E.	Julian Day. J	Computed Max. J	O – C. d
1	– 19	2413353	2413357·2	–4·2
2	19	2413355	2413357·2	–2·2
3	18	2413447	2413447·6	–0·6
4	16	2413627	2413628·6	–1·6
5	16	2413629	2413628·6	+0·4
6	15	2413727	2413719·1	+7·9

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Rotation No.	E.	Julian Day.	Computed Max.	O–C.
		J	J	d
7	− 15	2413729	2413719·1	+9·9
8	14	2413806	2413809·5	−3·5
9	11	2414077	2414080·9	−3·9
10	7	2414444	2414442·8	+1·2
11	6	2414534	2414533·3	+0·7
12	4	2414711	2414714·2	−3·2
13	3	2414809	2414804·7	+4·3
14	− 2	2414895	2414895·2	−0·2
15	0	2415076	2415076·1	−0·1
16	+ 1	2415164	2415166·6	−2·6
17	2	2415257	2415257·0	0 0
18	5	2415528	2415528·5	−0·5
19	+ 6	2415619	2415618·9	+0·1

TABLE IV.

Minima Dates.

Rotation No.	E.	Julian Day.	Computed Min.	O–C.
		J	J	d
1	−19	2413310	2413313·1	−3·1
2	19	2413311	2413313·1	−2·1
3	18	2413405	2413403·5	+1·5
4	15	2413676	2413674·9	+1·1
5	15	2413680	2413674·9	+5·1
6	14	2413765	2413765·4	−0·4
7	7	2414398	2413898·7	−0·7
8	3	2414755	2413760·6	−5·6
9	− 2	2414849	2414851·1	−2·1
10	+ 1	2415122	2415122·5	−0·5
11	2	2415214	2415212·9	+1·1
12	5	2415485	2415484·4	+0·6
13	+ 6	2415578	2415574·8	+3·2

The average residual is :

	d.
Maxima dates	2·5
Minima dates	2·1

That the latter value is the smaller is due to the fact that the minimum of this star is much more distinctly defined than the maximum phase.

The important element

$$\mathrm{M}-m=44^{\mathrm{d}}{\cdot}1$$

agrees very closely with that determined by Colonel Markwick, forty-three days (*Monthly Notices, R.A.S.*, vol. lviii., p. 514), and indicates that the duration of the ascending period of variation is not markedly unequal to the descending period.

This practical equality between ascending and descending portions of the light curve is a feature of not a few long-period stars.

Colonel Markwick finds a lower limit of $10^{m}\cdot0$ for the variation of *T Centauri*, but I think this is due to his underestimate by more than a whole magnitude of the brightness of two of the comparison stars used by him. The two stars are :

		h	m	s	°	′	
Z.C. xiii.^{h}	2039	13	34	0	33	1·3	(1875)
	2082	13	34	36	33	7·9	

The mean brightness of both stars is given in the Zone Catalogue as $8\frac{3}{4}$ magnitude. They have been regularly used at Lovedale as comparison stars for *T Centauri*, and I estimate them as between 8·6 and 8·8 magnitude. They are both distinctly seen in a 1-inch glass.

Colonel Markwick however considers them as 10·0 magnitude, a value which I am convinced is $1\frac{1}{2}$ magnitude too faint.

If allowance be made for this disparity in the reference standards it will be found that the range of magnitude obtained by Markwick confirms that determined at Lovedale.

In one of his papers on this variable Colonel Markwick pointed out that the range of variation was subject to considerable irregularity. This irregularity can be well exemplified by charting down two full cycles, one cycle in 1900 and the other in 1901.

These light curves are given in plates 1 and 2. The apparent similarity between the curves, indicating apparently alternative primary and secondary minima, is fortuitous. There is no regular succession of bright and faint minima, as is the case in some of the better known long period variables.

What has been stated or determined in the preceding part of this paper is deduced directly and solely from recent observations. In the case of *T Centauri* we have fortunately some old observations which I think may reasonably be used either to correct or supplement results obtained from more recent data.

These observations are :—

		Mag.	
1752	June 2	7·0	Lacaille
1846	June 6	8·0	Washington Obsns.
1849	Feb. 13	8·9	„
	March 23	8·0	„
1862	April 17	6·0	Yarnall
1863	April 17	6·0	„

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	Mag.	
1870 Jan. 7	6·0	Yarnall.
Jan. 17	6·0	"
1872 May 4 May 14 May 27	7·5	Washington Obsns.
1873 June 17	7·0	Cordoba Obsns.
June 30	7·5	"
1874 July 2	6·8	"
July 3	7·5	"
July 4	7·3	"
July 11	7·0	"
1875 June 16	7·0	"

As an indication of the uncertainty which must belong to any determination based simply on meridian observations of magnitude, Colonel Markwick regards Lacaille's observation as taken near a maximum of the star. In my judgment the observation was taken near a minimum. In such uncertainty as this the observation must be set aside.

With regard to the early Washington observations we have more definite data to go upon. It is evident that a minimum took place on or about 1849 February 13. Yarnall's observations, also, clearly point to a maximum on or about 1862 April 17.

The Cordoba observations do not indicate a point of reference that we may accept with confidence. I think, however, that 1874 June 15 as the date of a maximum phase is not much in error.

In the *Astronomische Nachrichten*, No. 3269, Professor Pickering gives a valuable series of photographic magnitudes of *T Centauri.*

These indicate a minimum on 1893 July 27.

We have therefore the following four dates to which we may relate recent observations :—

		Julian Day.
1849 Feb. 13	Minimum	2396437
1862 April 17	Maximum	2401248
1874 June 15	"	2405690
1893 July 27	Minimum	2412672

It is found that a period of $90^{d}\cdot30$ will better satisfy the earlier measures than the period $90^{d}\cdot47$ determined from recent observations. The correspondence with this shorter period is as follows :—

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E.	Observed date.	Computed date.	O−C. d.
−206	2396437	2396430	+ 7
153	2401248	2401260	−12
104	2405690	2405685	+ 5
− 26	2412672	2412684	−12

If the larger value, $90^{d}\cdot47$, be related to the last observation the residual is only -7^{d}. It is evident, therefore, that the period of *T Centauri* is affected by some secular variation, the nature and amount of which we can only discover when a fuller series of observations has been secured.

The mean period of the star will probably be found to be not far from 90·3 days, with a range of from two to three days on either side of this mean period.

I would seek to acknowledge my great indebtedness to Sir David Gill and to Mr. R. T. A. Innes for their ever-ready willingness to make remoteness from a complete astronomical library less of a hindrance in investigations such as the preceding. They were good enough in the present instance to look up for me all the old records of *T Centauri.*

Lovedale: 1901 *October* 1.

On the Place of the Variable RU Herculis and Neighbouring Stars from Photographic Measures. By F. A. Bellamy, F.R.Met.Soc.

In No. 3384 of the *Astronomische Nachrichten* Dr. T. D. Anderson refers to a star of the ninth magnitude not given in B.D. He noted it as 9·1 magnitude in 1895 August; it was below the tenth magnitude on October 16, and became invisible later.

As there were several stars in the field of view of similar magnitudes, which rendered it difficult to identify the probable variable star with certainty, it seemed necessary that the position of it should be accurately determined, and this Dr. Hartwig did by measurement from two stars in the Cambridge and Berlin A.G. Catalogues with the heliometer; his results are included in an article on variable stars in *Astronomische Nachrichten*, 3553, and the positions given are

$$1900\cdot0 \text{ R.A. } 16^{h}\ 6^{m}\ 2^{s}\cdot76 \qquad +25^{\circ}\ 19'\ 54''\cdot7$$

and he adds a note to the effect that his observation was rendered difficult by the low altitude of the star and atmospheric conditions.

This star is in the region apportioned to this observatory for